Interoperability of Airborne Collision Avoidance Systems

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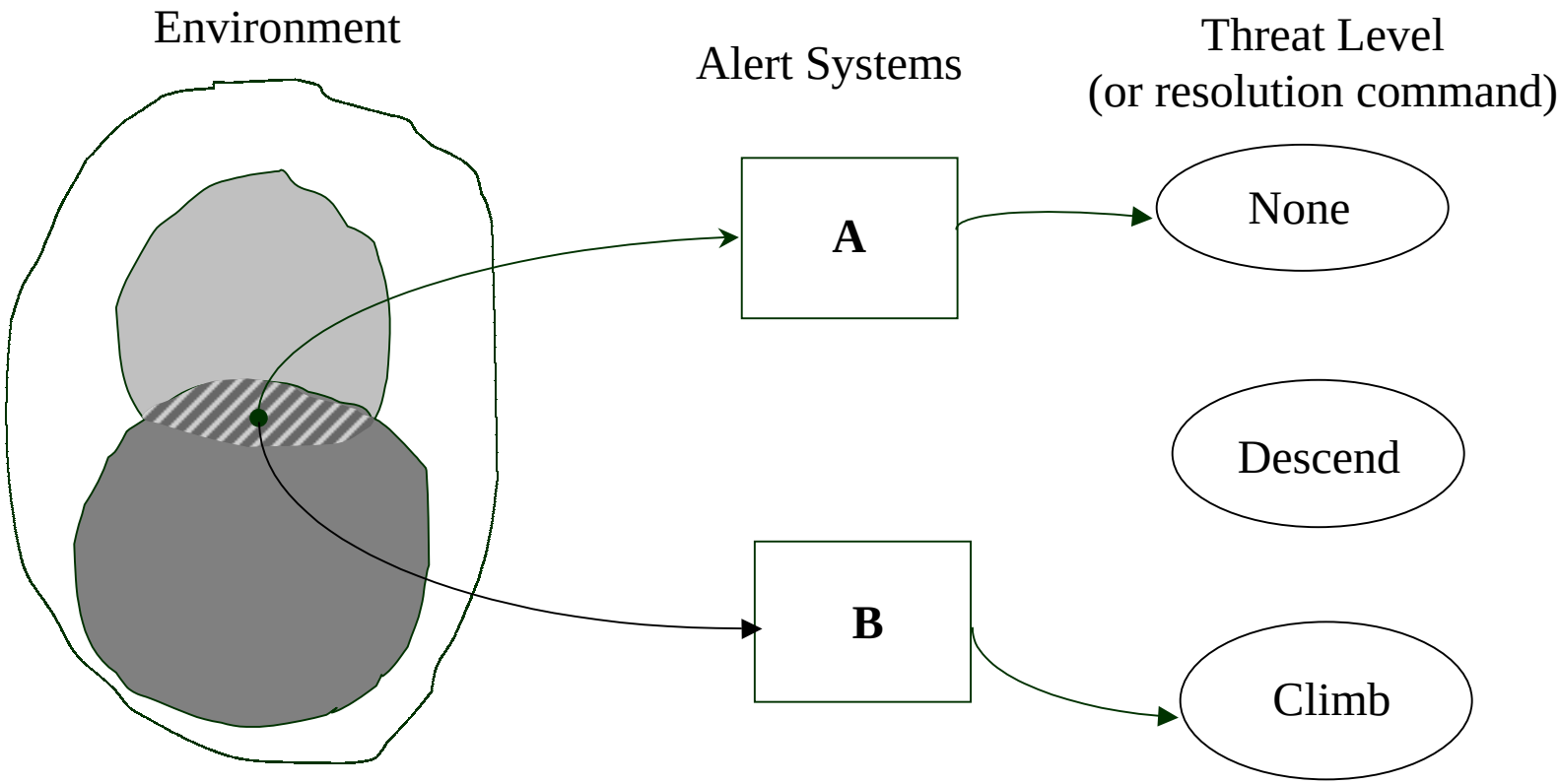
Review of Airborne Collision Avoidance systems

- **Traffic Alert and Collision Avoidance System (TCAS) on aircraft since 1980s**
- **Datalink (ADS-B) based conflict detection system proposed**
  - ❑ Airborne Conflict Management (ACM)
  - ❑ Currently being evaluated in operational tests by UPS/FAA
    - ◆ Leapfrog TCAS requirement for cargo airlines
  - ❑ Initial specifications & design issues being investigated by RTCA subcommittee
- **Will the two systems operate harmoniously?**

Conflict between Multiple Alerting Systems



Dissonance may occur whenever a given state maps into two different alert stages or two different resolution commands or when the time-derivatives of these mappings differ

TCAS---Traffic Alert and Collision Avoidance System

- **Designed to alert flight crews to potential mid-air collisions**
- **Range, range rate, altitude and altitude rate between two aircraft available through radar**
- **Includes TA (Traffic Advisories) and RA (Resolution Advisories)**
  - ❑ TAs direct the crew's attention to a potential threat, but no avoidance information is provided
  - ❑ RAs provide avoidance commands such as "Climb" or "Descend"
- **Maximum look ahead limited by lack of good trajectory information (~30 seconds)**

Graphical Relationship Viewed from Above (TCAS)

- **Alert Based on estimated time to reach DMOD separation**

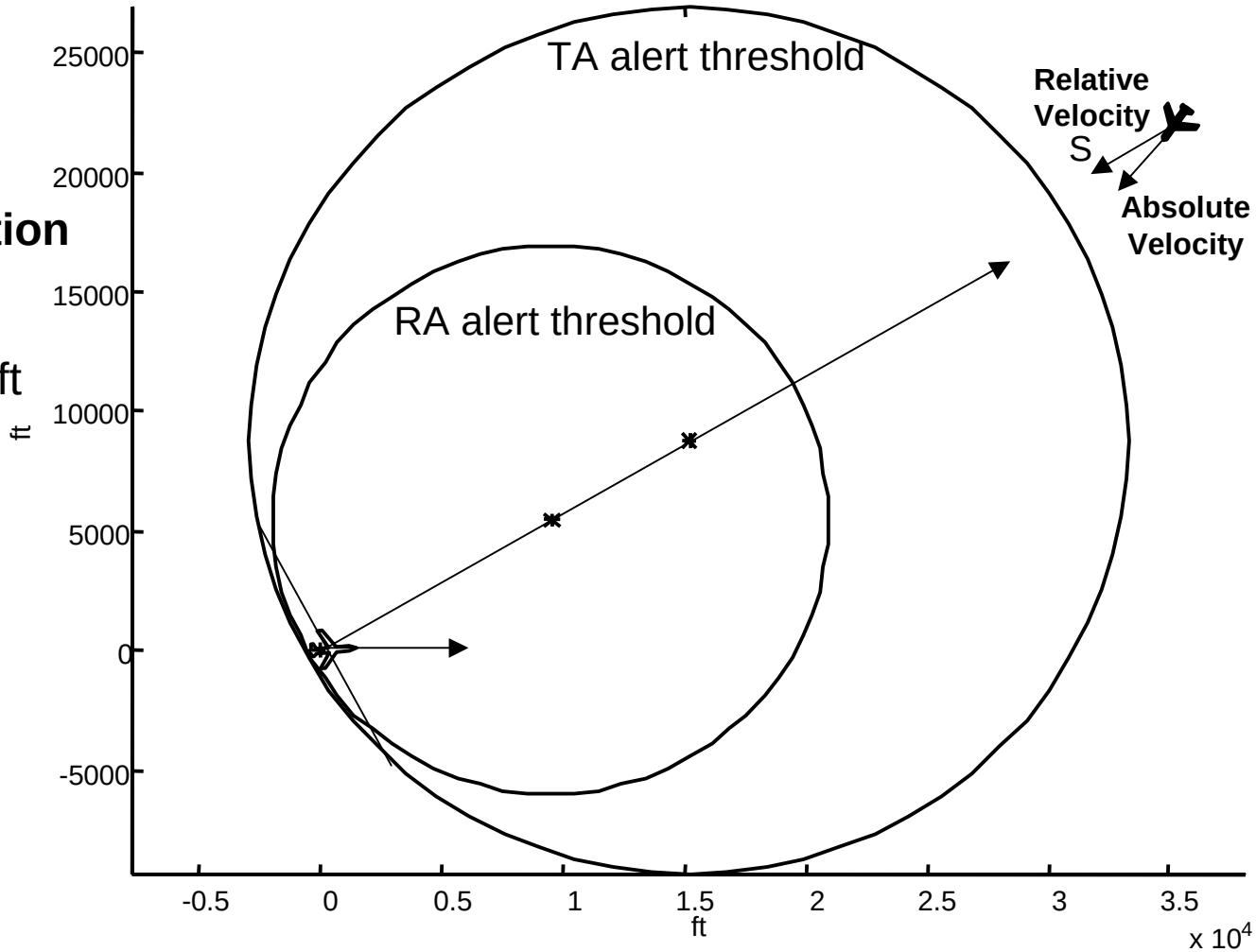
At level 5
Altitude: 9500ft-20500ft

DMOD_TA=0.75 nmi

DMOD_RA=0.55 nmi

Tau_TA=40s

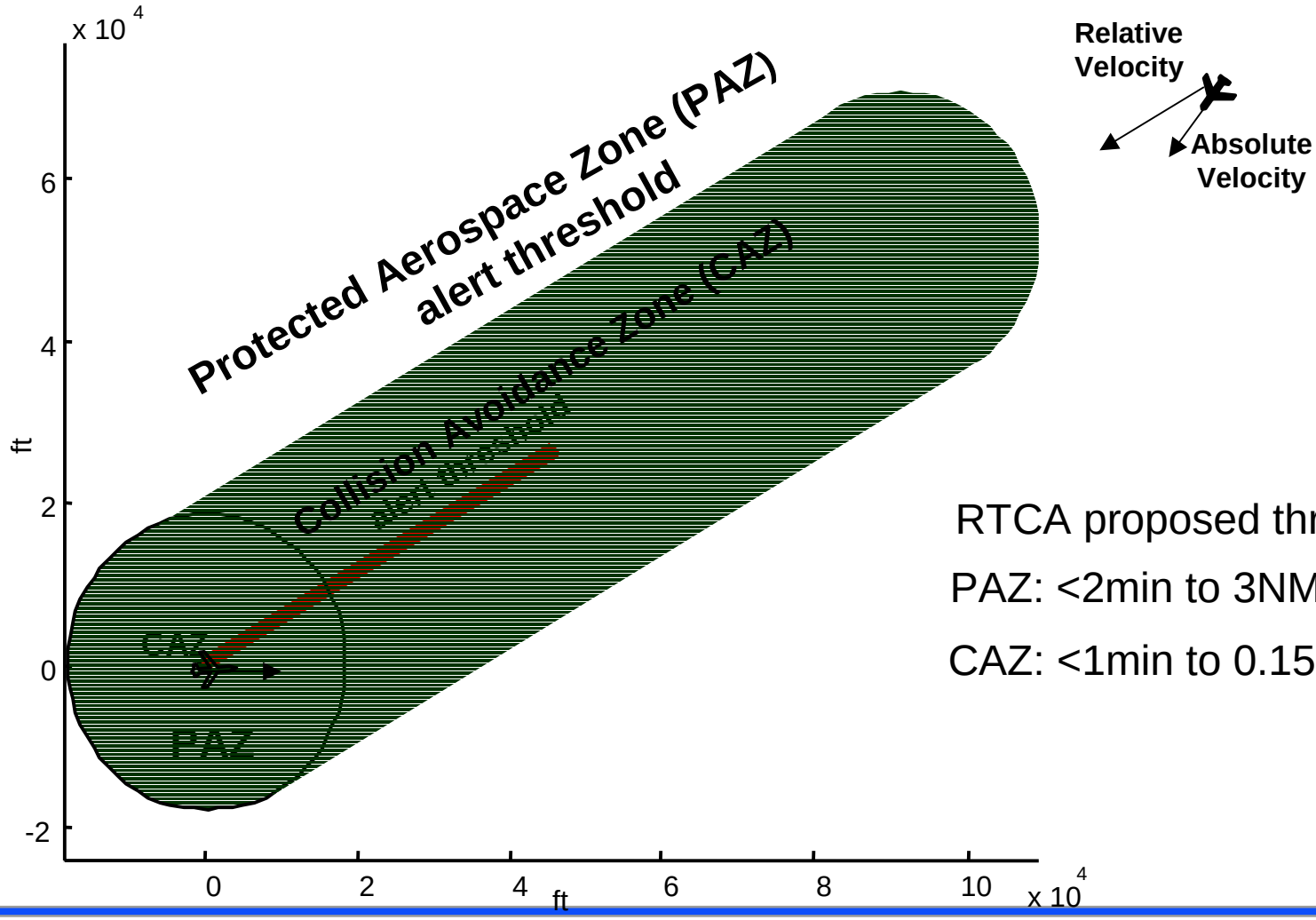
Tau_RA=25s



ACM---Airborne Conflict Management

- **The state vector and intent available through ADS-B (data link-based)**
  - ❑ Improved trajectory information (velocity vector, way points, etc.)
  - ❑ Enable longer look ahead than TCAS
  - ❑ Enable new procedures (in-trail spacing) using enhanced display
- **Basic assumptions of ACM**
  - ❑ ACM will function properly during other applications such as visual approach or approach spacing
  - ❑ ACM will be installed on A/C with TCAS as well as A/C without TCAS

Graphical Relationship Viewed from Above (ACM)



RTCA proposed thresholds:

PAZ: <2min to 3NM separation

CAZ: <1min to 0.15NM separation

ACM/TCAS Interoperability Amongst Aircraft

- **“Interoperability” refers to the successful, simultaneous of the two systems**
- **Operation of TCAS will not be changed (ACM is an add-on similar to EGPWS)**
- **TCAS and ACM surveillance information are different**
  - ❑ TCAS measures relative range and bearing
  - ❑ ACM receives the broadcast state vector and intent
- **Any possible relationship and interdependence between ACM TCAS must be investigated**

ACM and TCAS Installed on Same Aircraft

- **In an integrated TCAS/ACM system, it is important to display one real-time target for each actual aircraft**
- **It's been proposed by RTCA that an alert will be presented to crew when issued by either system until there is no alert by system**
- **The information and advisories generated by the ACM and should not conflict with each other, or cause pilot confusion**
- **Need to prevent dynamic conflict between ACM and TCAS**
  - ❑ TCAS → ACM
  - ❑ ACM → TCAS

ACM on One Aircraft and on the Other

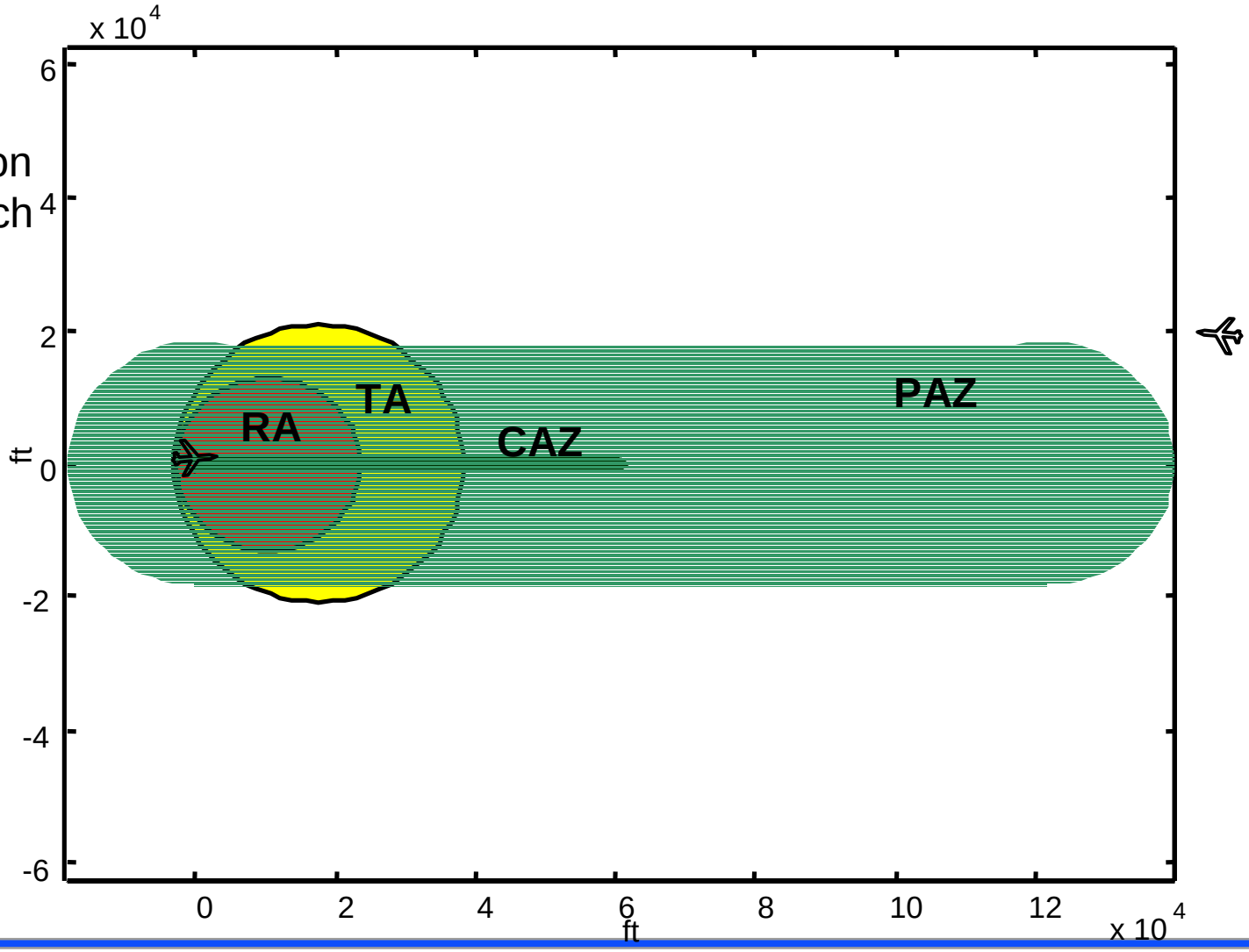
- **Both aircraft can detect each other with their respective ADS-B available on both aircraft, but different systems may be issuing resolution advisories**
- **Problem exists if the systems issue incompatible resolutions**
- **An analysis must be performed to determine if there is a significant probability that the ACM would issue resolution advisories incompatible with TCAS advisories**
- **An analysis must be performed to prevent dynamic conflict between ACM and TCAS**
  - ACM on one aircraft → TCAS on another aircraft
  - TCAS on one aircraft → ACM on another aircraft

Unresolved Issues in the Integration of TCAS and ACM

- **TCAS/ACM Conflict Alert Integration**
  - ❑ Does the crew need to know which system is generating the alert?
  - ❑ How to handle ACM alert which becomes TCAS alert? (& vice-versa)
  - ❑ Will TCAS alert when ACM says there is no problem?
- **TCAS/ACM Resolution Integration**
  - ❑ How much coordination is required between systems installed on the plane, or on conflicting aircraft?
  - ❑ What is the goal of PAZ Resolution Advisories?
    - ◆ To maximize miss distance
    - ◆ To get out of PAZ as soon as possible
    - ◆ To minimize the likelihood of TCAS alert

Scaled TCAS and ACM Logic

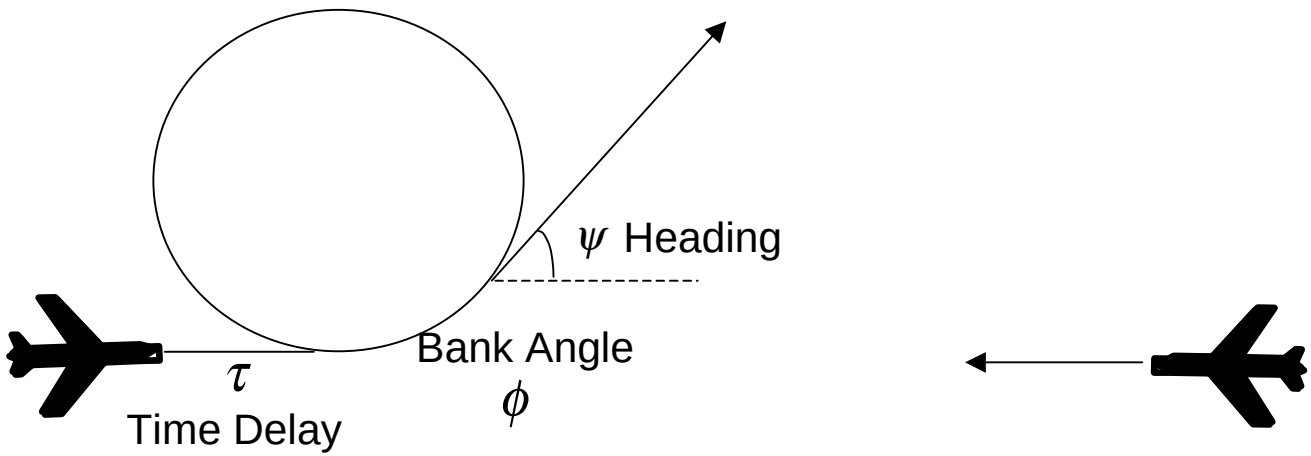
- Both aircraft opposite direction at 300 knots each



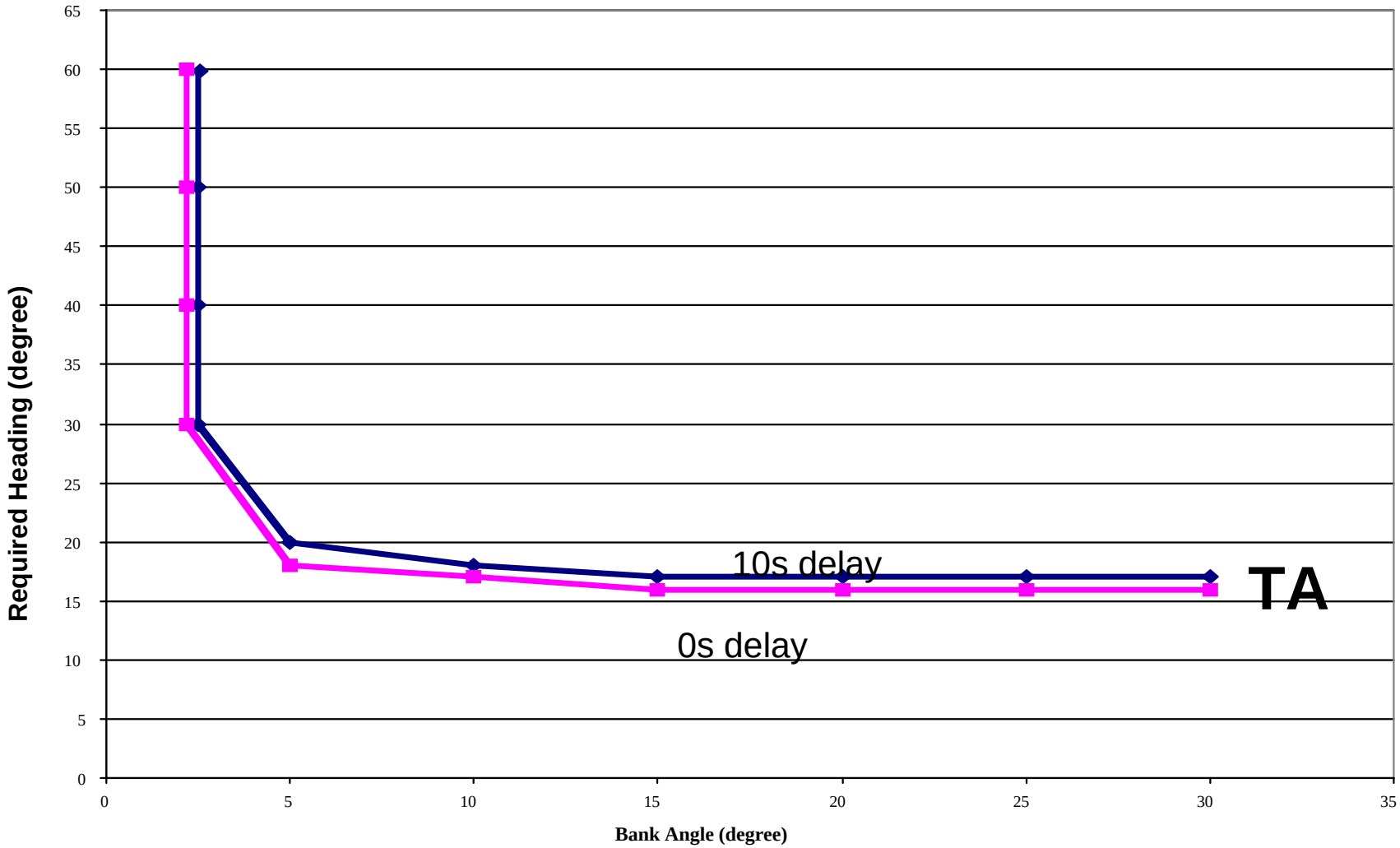
Required Minimum Maneuver to Avoid TCAS Alert following ACM Alert (Turn)

Model: Opposite direction aircraft at the same altitude

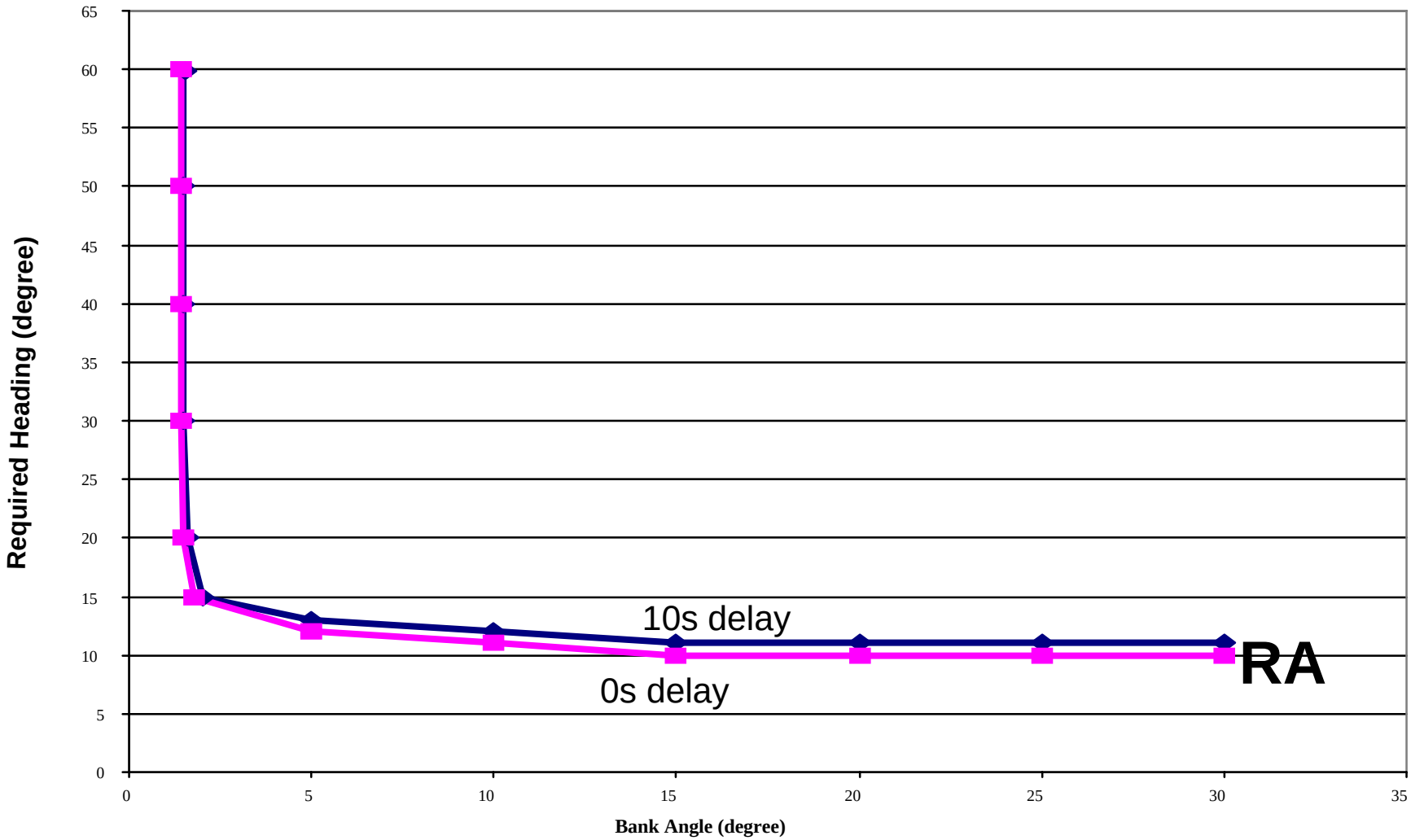
With 200 knots for each aircraft



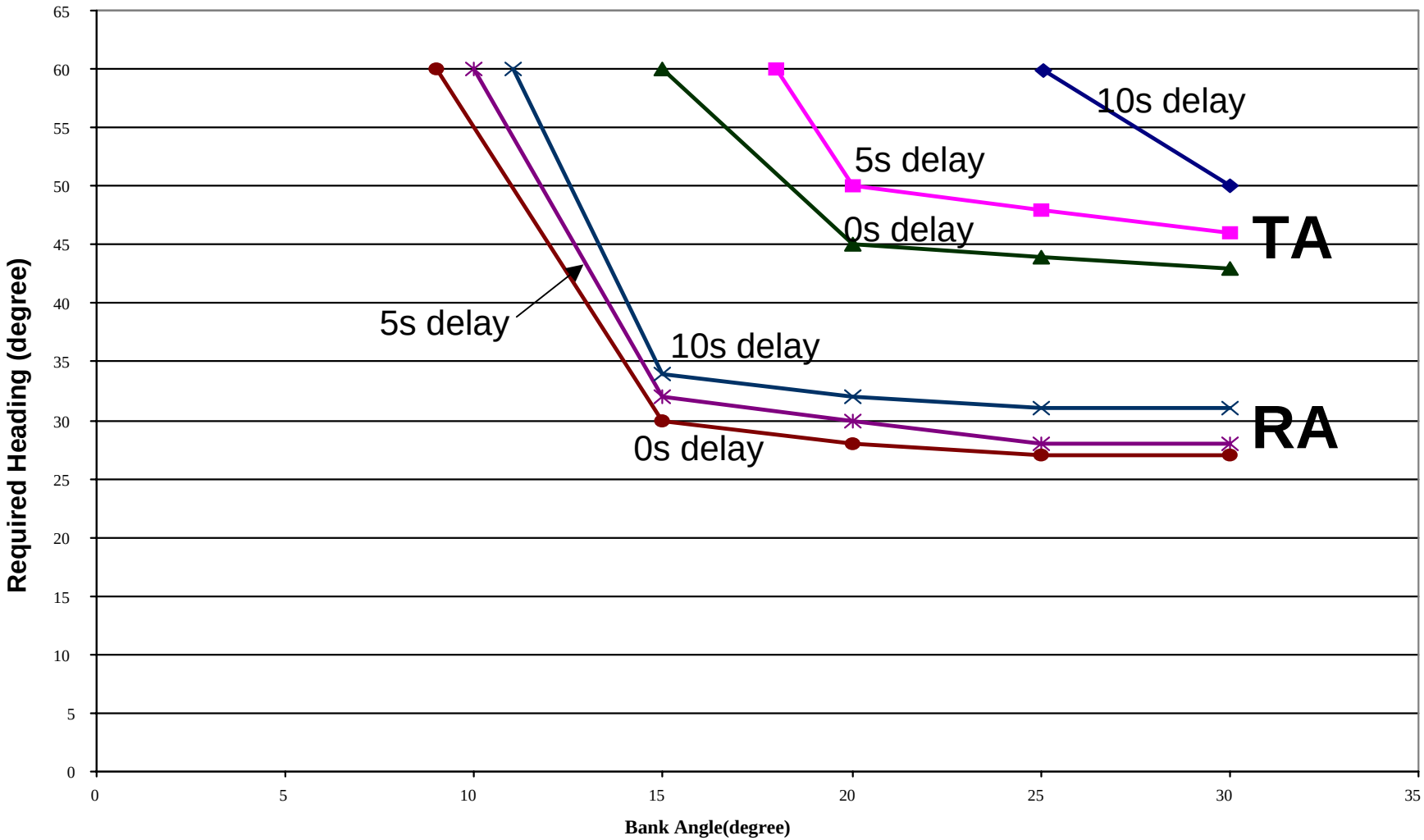
Turning Maneuver for PAZ to Avoid TCAS TA



Turning Maneuver for PAZ to Avoid TCAS RA

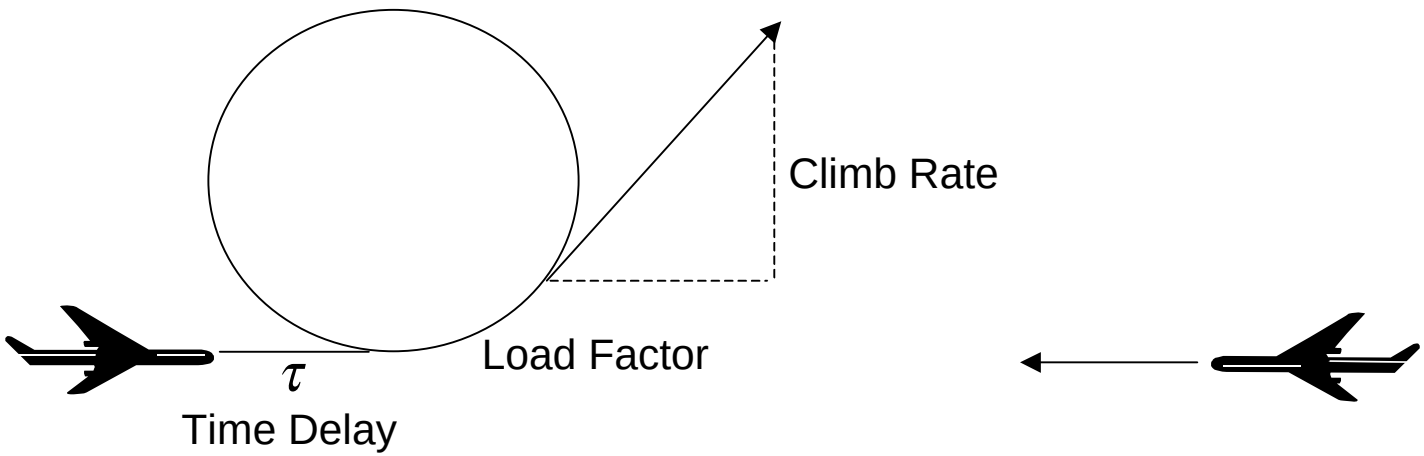


Turning Maneuver for CAZ to Avoid TCAS Alert

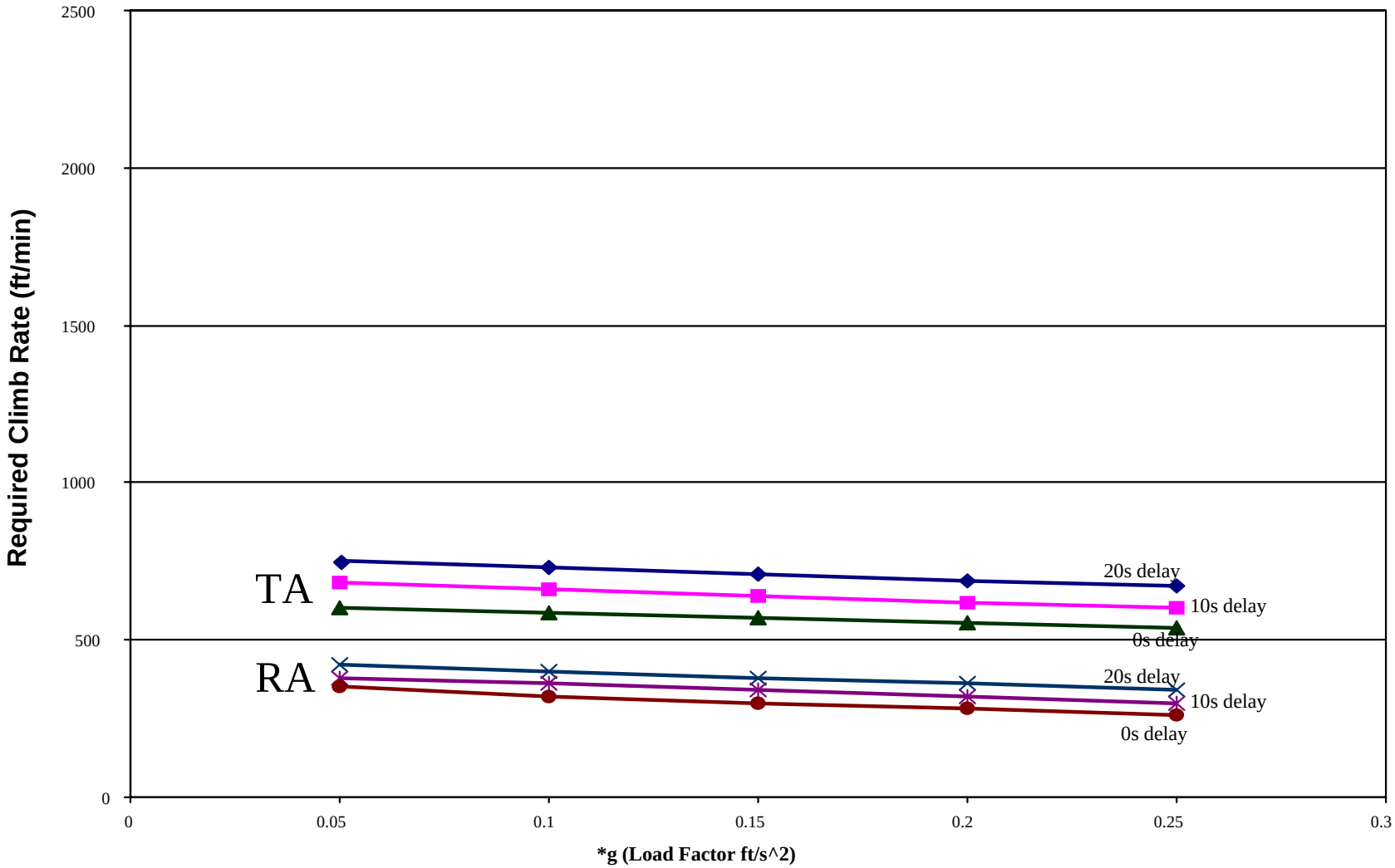


Required Minimum Maneuver to Avoid TCAS Alert following ACM Alert (Climb)

Model: Opposite direction aircraft at the same altitude with 200 knots for each aircraft



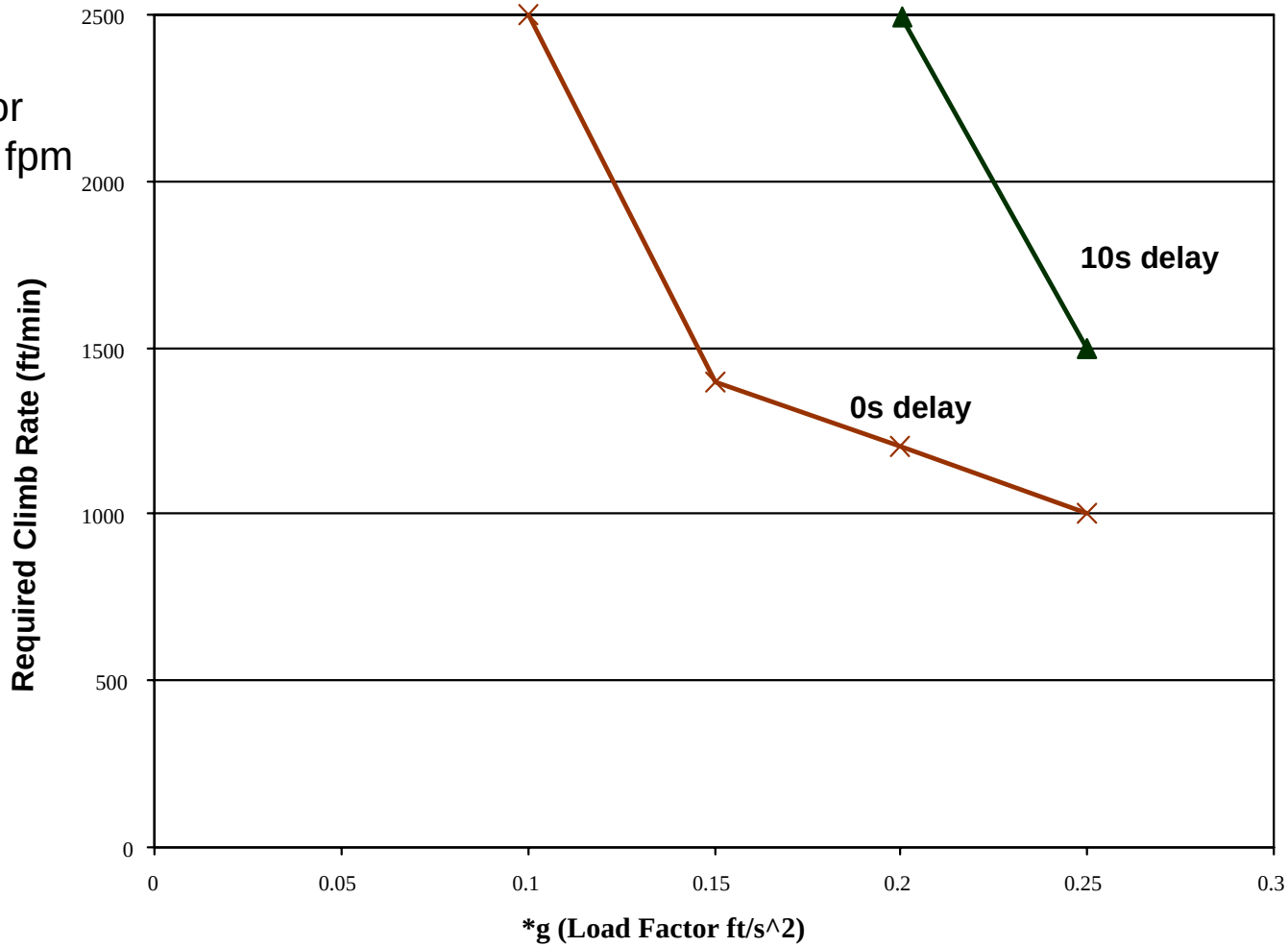
Climb Maneuver for PAZ to Avoid TCAS Alert



Climb Maneuver for CAZ to Avoid TCAS RA

To avoid TCAS TA

Need 1.6g load factor with Clime Rate=2500 fpm and 0s delay



Summary

- **Initial suggestions for PAZ & CAZ dimensions do not appear to allow responding to ACM alert without later receiving a TCAS (must be aggressive)**
  - ❑ Longer look ahead would reduce required maneuver but increase alert rate
  - ❑ Does it make sense that CAZ alert nearly always becomes a TCAS alert
- **Potential for TCAS False Alarm with no ACM alert**
  - ❑ Worse as closure rate increases
- **Future Objectives**
  - ❑ TCAS alert affect ACM alert needs to be examined
  - ❑ Apply the formal model to the analysis of TCAS/ACM